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APPLICATION FOR LETTERS PATENT:

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Heat Exchanging Fluid Return Manifold For A Liquid Cooling System

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INVENTORS

Paul A. Knight

John D. Schwarzkopf

Charles L. Tilton

DOCKET #: ISR-197

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CROSS REFERENCE TO RELATED APPLICATIONS

[0001] We claim benefit under Title 35, United States Code, Section 120 of United States patent application Serial Number 10/371,403 filed February 19, 2003 entitle "Coolant Recovery System". This application is a continuation-in-part of the 10/371,403 application which is currently pending and is hereby incorporated by reference into this application.

STATEMENT REGARDING FEDERALLY SPONSORED RESEARCH OR DEVELOPMENT

[0002] Not related to this application.

BACKGROUND

Field of the Invention

[0003] The present invention relates generally to liquid cooling thermal management systems and more specifically it relates to a two-phase liquid cooling management system.

Description of the Related Art

[0004] Liquid cooling is well known in the art of cooling electronics. As air cooling heat sinks continue to be pushed to new performance levels, so has their cost, complexity, and weight. Liquid cooling systems provide advantages over air cooling systems in terms of heat removal rates, component reliability and package size.

[0005] Liquid cooling systems are comprised of many different species. Although each specie may have unique advantages and disadvantages, they are all designed to perform the same goal: remove heat from an electronic component. Generally, liquid coolant is placed in thermal contact with a component to be cooled wherein energy is transferred from the higher temperature component to the coolant. A pump circulates the liquid through the closed system, thus allowing the cooling fluid to continuously transfer thermal energy from the component to be cooled and to a desired location. Typically, the absorbed heat is removed from the cooling fluid through the use of a heat exchanger. Species of liquid cooling systems can be lumped into two categories: single-phase and two-phase. The phase signifies how the cooling fluid absorbs and exchanges energy.

[0006] Single-phase liquid cooling utilizes a pure liquid for absorbing heat from the component to be cooled. Energy is absorbed by the coolant through sensible heat gains. The temperature of the coolant increases as energy is absorbed according to well known engineering formulas. An example of a

single-phase liquid cooling system is described by U.S. Pat. No. 6,234,240. Due to the simple nature of single-phase fluid flow and sensible heat gains, single-phase liquid cooling solutions are fairly straight-forward to design and implement.

[0007] The preferred method of liquid cooling is two-phase. A two-phase system absorbs energy from the component to be cooled by means of latent heat gains of its fluid. The temperature of the coolant does not necessarily change, but rather part of the coolant is vaporized as energy is absorbed. The vaporized coolant is then transferred to a heat exchanger, or condenser, where energy is removed from the vapor causing it to transform back to a liquid state. An exemplary two-phase cooling solution is described by U.S. Pat. No. 5,220,804, which describes how atomization of the cooling fluid, along with vapor management within the spray module, provides high heat flux thin film evaporative cooling.

[0008] The advantages of two-phase cooling over single-phase cooling are significant. Due to the amount of energy needed to vaporize a liquid in comparison to the energy required to raise its temperature, two-phase systems provide the ability to have more compact components, require less input energy and provide higher heat removal performance than single-phase systems.

[0009] Although both single-phase and two-phase liquid cooling solutions provide many advantages over air cooling solutions, they also have drawbacks. One such drawback is that liquid cooling can be more expensive than air cooling. In the case of a single processor application, an air cooling heat sink may be

comprised of an aluminum extrusion and a fan. In the case of liquid cooling, for each processor, a pump, a heat exchanger, tubing, fittings, fluid and a thermal management unit are needed. Although the performance of liquid cooling may justify the increased cost over air cooling, liquid cooling a single processor may require a cost premium.

[0010] One of the ways to reduce costs of liquid cooling solutions is to cool multiple electronic components from a single closed loop liquid cooling system. In the case of a rack full of servers, many computer systems may be chained together. The result is a significant savings through economies of scale. Chaining electronic components together can be accomplished in two ways: parallel and series connections.

[0011] With series connections, the fluid is routed from one heat generating component to another, until all units have been cooled. Although this method is largely used with single phase systems, it can also be used with two-phase systems. A significant problem with series connections is that the cooling fluid is at a different thermal state at each electronic component along the chain. As one processor may go from a max power consumption state to an idle state, that processor may create a thermal cycle for the other processors in the system. Thermal cycling reduces component reliability.

[0012] With parallel connections, the fluid is routed from the pump directly to all components to be cooled. The fluid is also removed from the thermal management units via individual parallel branches. A prior art return system is

shown in Figure **1** of the attached drawings wherein each thermal management unit has a unique fluid path. Although this type of connection is used primarily with two-phase systems, it can be used with single-phase systems as well. Parallel connections remedy the disadvantages of series connections, but it too creates challenges.

[0013] A first challenge with parallel connections using two-phase flow is that the flow of fluid can be complicated. Vapor is significantly less dense than liquid and thus the mixture can create multiple flow patterns including: annular, slug and froth. The mode of flow can be difficult to predict and tests have shown the mode of flow to have a significant impact on the performance of a cooling system.

[0014] Another problem with parallel connections is that the numerous transitions can cause system back-pressures. Back-pressures, or restrictions downstream of a spray module, can cause an increased pressure level within a spray module and may result in reduced cooling performances.

[0015] Another problem with parallel connections is that in many computer cooling applications, the locations of particular processors may not be fixed. The parallel connections of the cooling system must be created in a fashion that provides configuration flexibility.

[0016] Thus, there is a need for a two-phase parallel liquid cooling solution capable of cooling many electronic components in non-specific configurations. It

is highly desirable for such a system to provide consistent cooling performance under a wide range of conditions.

BRIEF SUMMARY OF THE INVENTION

[0017] In order to solve the problems of the prior art, and to provide a liquid cooling solution that allows multiple components to be cooled in parallel, a heat exchanging fluid return manifold has been developed.

The present invention is a two-phase liquid cooling system that cools a plurality of electronic components connected in parallel. A pump delivers a cooling fluid, as a liquid, to a supply manifold wherein it splits into distinct branch lines. Preferably, the branch lines feed coolant to individual spray modules. The liquid coolant removes heat from the components to be cooled through evaporation. The resulting liquid and vapor mixture exits the spray modules via return branches. Each individual return branch feeds into a return manifold wherein the manifold is sized sufficiently for the separation of liquid and vapor under the influences of gravity. In addition, a heat exchanger is located within the return manifold and provides for the condensation of vapor. The heat exchanger may also provide liquid subcooling.

[0018] These and other features, aspects, and advantages of the present invention will become better understood with regard to the following description, and accompanying drawings

BRIEF DESCRIPTION OF THE DRAWINGS

[0019] In the course of the detailed description to follow, reference will be made to the attached drawings. These drawings show different aspects of the present invention and, where appropriate, reference numerals illustrating like structures, components, and/or elements in different figures are labeled similarly. It is understood that various combinations of the structures, components, and/or elements other than those specifically shown are contemplated and within the scope of the present invention:

[0020] Figure **1** is a block diagram of a prior art thermal management system having a plurality of thermal management units fluidly connected in parallel;

[0021] Figure **2** is a block diagram of a liquid cooling system according to the present invention;

[0022] Figure **3** is a front view of an electronic system supporting multiple electronics enclosures, each containing heat generating electronic components that are cooled by the liquid cooling system of Figure **2**;

[0023] Figure **4** is a partial perspective view showing the heat exchange return manifold of Figure **3**;

[0024] Figure **5** is a top partial view of the right side of the electronic system of Figure **3**, wherein the heat exchange return manifold is shown mounted in front of the right rack rail and without a cap, for clarity;

[0025] Figure **6** is a top partial view of the right side of the electronic system of Figure **4**, wherein the heat exchange return manifold is shown mounted integral to the rack rail and without a cap, for clairy; in addition, an alternative square exchange fluid channel is shown;

[0026] Figure **7**, is a top partial view of the right side of an alternative cooling panel version of the liquid cooling system of Figure **2**;

[0027] Figure **8**, is a round alternative embodiment of the heat exchange return manifold according the present invention; and

[0028] Figure **9**, is a finned alternative embodiment of the round embodiment of the present invention shown in Figure **8.**

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

[0029] Many of the fastening, connection, manufacturing and other means and components utilized in this invention are widely known and used in the field of the invention are described, and their exact nature or type is not necessary for a person of ordinary skill in the art or science to understand the invention; therefore they will not be discussed in detail.

[0030] Applicant hereby incorporates by reference U.S. Patent No. 5,220,804 for a high heat flux evaporative cooling system. Although spray cooling is herein described as the preferred method of two-phase cooling, the present invention is not limited to such a system. Spray cooling is only discussed in detail to provide a known preferred embodiment. In addition to two-phase spray cooling, the present invention is applicable to, but not limited to, single-phase cooling and refrigeration systems.

[0031] Figure **2** shows a liquid cooling system **20**, according to the present invention. A plurality of thermal management units **22,** such as described by U.S. Patent No. 5,220,804, are thermally connected to a plurality of heat generating electronic components (not shown). A supply liquid **70** is pressurized by a pump **51** within a pump system **50**. Supply liquid **70** may be any commonly known or used cooling fluid, including but not limited to Fluorinert (a trademark of 3M). The supply liquid **70** may also be a multi-component fluid, such as but not limited to water-air mixtures. Pump system **50** may include a reservoir **52** for providing a continuous supply of liquid coolant to pump **51** and other liquid

cooling components such as, but not limited to, fluid filters and control system components. After exiting pump system **50,** supply liquid **70** is delivered to a supply manifold **71** wherein it is dispersed to a plurality of supply branches **72.** Each of supply branches **72** delivers a portion of supply liquid **70** to a thermal management unit **22.** Supply liquid **70** within thermal management unit **22,** absorbs heat from the one or more electronic components. The absorbed heat continuously transforms supply fluid **70** into a return fluid **73.** Preferably, return fluid **73** is a two-phase fluid. Wherein return fluid **73** is a multi-component mixture, at least one of the components is transformed to a two-phase fluid within unit **22.** A plurality of control valves **24** provides the means of controlling the heat absorption rate of each management unit **22** and the quality of return fluid **73.** Control valve **24** also provide the means of equalizing pressures across the plurality of management unit **22** caused by varying head pressures. A plurality of return branches **74** removes return fluid **73** from the plurality of management units **22.**

[0032] Unlike the prior art, portions of return fluid **73** within the plurality of return branches **74** do not rejoin in a manifold prior to being delivered to a heat exchanger. Also, unlike the prior art, portions of return fluid **73** within the plurality of return branches **74** do not rejoin in a manifold prior to being delivered to a separator. Liquid cooling system **20,** and according to the present invention, utilizes a novel heat exchange return manifold **30.**

[0033] Heat exchange return manifold **30** is comprised of a return channel **34,** a cap **31** and a vent valve **32**. Heat exchange return manifold **30** provides the means of removing energy from return fluid **73** while minimizing system backpressures. Return channel **34** is sized sufficiently to allow for gravity driven liquid – vapor separation within, wherein the liquid is encouraged to fall. Unlike the liquid, non-condensable gasses are encouraged to rise to vent valve **32** where they can be purged from the system. Non-condensable gases may be in solution within the liquid cooling fluid and then separated through the evaporation process. For optimal system performance it is desirable to remove non-condensable gases from the system.

[0034] In addition to liquid – vapor - gas separation, return channel **34** is preferably sized sufficiently to house an exchange channel **78**. Exchange channel **78** contains a flow of an exchange fluid **75**, such as but not limited to facility water, chilled air, or fluid from a secondary cooling system. The thermal connection between the colder exchange fluid **75** and warmer return channel **34**, results in an energy exchange according to well known heat transfer principles and heat exchanger design. The flow and temperature of exchange fluid **75** is sufficient to absorb energy at the same rate that the plurality of electronic components produce it. The result is the condensing of vapor within heat exchange manifold return **30** and the ability to transport the released energy from the electronic components to a desired location, such as but not limited to outside a building. If it is desirable to exchange heat with the local environment

return manifold **30** may be constructed from a thermally conductive material such as aluminum. Oppositely, if it is desirable to not exchange heat with the local environment, return manifold **30** may be constructed from an insulating material such as plastic. The construction and assembly methods for return manifold **30** are common to well known engineering and design practices. It is desirable to construct exchange chamber **78** in a fashion that promotes thin film condensing and resists fluid pileups.

[0035] Figure **4** shows heat exchange return manifold **30** in further detail. The plurality of return branches **72,** each carrying a portion of return fluid **73,** preferably join heat exchange return manifold **30** at acute angle, as described by U.S. Patent Application 10/769,259 entitled "Low Momentum Loss Fluid Manifold System" filed on January 30, 2004, herein incorporated by this reference. Although the described method of reducing momentum loss is preferable, return branch **72** may perpendicularly join heat exchange return manifold **30**. The acute angle further reduces system backpressures and further encourages liquid to fall in the direction of gravity. Also shown in Figure **4** is exchange chamber **78**. Exchange fluid **75** enters exchange chamber **78** through inlet **76**. After exchange fluid **75** absorbs energy from return fluid **73** it travels through exit **77**. Although the shape of exchange chamber **78**, as shown in figure **4**, is ideal for having the fluid enter and exit through the same side, the present invention is not limited to such a configuration. It is possible to have exchange fluid **75** enter or exit from opposite sides.

[0036] Figure **3** shows a preferred application of the present invention. An electronics system **40** is shown, typical of a system found in data-networks and teleco-networks. A rack **41** is mounted to a floor by a base **42**. A left rail **45** and a right rail **44** extend upwards from base **42** and are connected to and support a top **43**. Rails **44** and **45** provide the means for mounting a one or more electronics enclosure **47.** The one or more electronics enclosure **47** houses heat generating electronic components and the plurality of thermal management units **22**. Electronics enclosure **47** may be, but is not limited to being a router, hub, switch, server, or computer system. It should be known to one skilled in the art that rack **41** is not limited to an open channel rack as shown, instead it may be part of a cabinet type system. It should also be known that multiples of electronic system **40** may be placed side by side to form a lineup.

[0037] One of the many benefits of heat exchange return manifold **30** is that significant amounts of heat can be exchanged by a single cooling system; thus providing significant economies of scale and reductions in cost. Heat exchange return manifold **30** may be placed in numerous locations within electronic system **40** and locations in a lineup. Each optimal location may be application specific and partly a function of the type of electronics used, type and quantity of cables connecting the electronics, and the total amount of heat generated. Figure **5** shows a square embodiment of heat exchange return manifold **30** mounted directly in front of left rail **45**. By utilizing quick disconnect fittings **39**, such as are commercially available from Colder Products Company,

the embodiment of Figure **5** provides the opportunity to place electronics system **40** against a wall and still retain configuration flexibility. Heat exchange return manifold **30** may also be mounted along left rail **45**, or behind either rail **44** or **45**.

[0038] Figure **6** shows an alternative rack-integrated embodiment of the present invention wherein heat exchange return manifold **30** is captured by part or all of rails **44** or **45**. This embodiment provides protection of the liquid within heat exchange return manifold **30** and takes advantage of a typically unutilized portion of rack **41**. Also shown in Figure **6** is a square version of exchange channel **78**.

[0039] Figure **7** shows a stand-alone version of liquid cooling system **20** according to the present invention. A cooling panel system **60** is placed adjacent and in fluid connection with rack **41**. Panel **60** houses all the system components contained within pump system **50**, thus freeing further space within rack **41** for housing electronic components. Unlike the previous embodiments, panel system **60** is not constrained in size to rack **41**. Panel system **60** may be sized to remove very large amounts of heat, sufficient to potentially cool multiples of electronic system **40** in a lineup, resulting in further improvements in economies of scale. Cooling panel systems **60** may be structurally supported by rack **41**, or may be independently secured to ground.

[0040] Figure **8** and Figure **9** shows a coaxial version of heat exchange return manifold **30** which further supports that manifold **30** can be made from a wide range of shapes. Figure **9** shows both exchange fins **38** and return fins **39**

which increase contact area and resulting heat transfer rates between exchange fluid **75** and return fluid **73**. Both, or either, of fins **38** and **39** may be used with the aforementioned embodiments. A wide range of shapes of fins **38** and **39** are possible by making heat exchange return manifold from extruded aluminum.

[0041] While the heat exchanging fluid return manifold system herein described constitutes preferred embodiments of the invention, it is to be understood that the invention is not limited to these precise forms of assemblies, and that changes may be made therein with out departing from the scope and spirit of the invention.